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OCEAN WATER COLOR ASSESSMENT FROM ERTS-1 RBV AND MSS IMAGERY

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16. Abstract

RBV1, and -2 9 1/2-inch images of the Caribbean test area were corrected to reduce residual radiometric errors by masking. RBV-1, -2 and MSS-4 images were reproduced at higher gammas to reduce contrast degradation caused by the atmosphere and sensor response of less than 20% full scale. Resultant high densities and lengthy exposures required to print through during subsequent masking steps created technical problems, and undependable sensitometric control data. Work has been re-started with intermediate images at lower reproduction gammas, and lesser density ranges. Final gamma corrections for scene contrast will be applied to the images in the last stages. Several film types were tested for linear reproduction at lower densities, and are being used.

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SUMMARY OF WORK DURING PERIOD

2. The means of estimating atmospheric effects for scene contrast degradation described in the last Progress Report (8 May - 7 Jul 1973) was extended to RBV bands 1 and 2. 9 1/2 inch working positive images of RBV-1 and -2 were made, corrected to reduce residual radiometric errors. The modified masking procedure described previously was carried out with a new system of control step tablet placement to permit closer sensitometric control of intermediate images. High-gamma scene contrast correction, with RBV-2 and MSS-4 images was applied in the initial masking steps, but the densities resulting in the working positive and masking negative proved to be excessive for subsequent printing. The long exposures required caused halation and a deterioration of control step tablet images in the masked reproduced image. Following the same masking approach, a fresh start has been made to perform scene contrast correction in several steps at lower gammas and densities, reserving full scene contrast corrections for reproduction of the final, masked images. New film types were tested and used, to ensure linear reproduction of key image densities at lower density levels.

CONFORMANCE WITH WORK SCHEDULE

3. Approval was received for starting Phase III in April 1973. Phase III termination date has now been extended from 24 Aug to 24 Oct 1973. The

work is on schedule for completion by the new date.

PROGRESS

4. In the Progress Report for 8 May - 7 Jul 1973 a way was described for estimating ocean scene contrast degradation, caused by the combined effects of atmospheric haze, and sensor-fall-off at levels of 20% of full scale response, or less. It was estimated that deep water ocean scene reflectances in the order of 4% to 10% were actually reproduced in the NASA/GSFC positives at the following relative gammas:

MSS-4 $\gamma 0.19$

MSS-5 $\gamma 0.32$

It was assumed that the same ocean areas in the equivalent RBV-1 and -2 spectral bands would also be very close to the gammas in the MSS bands. (As RBV-1 spectral response extends further toward the blue region than MSS-4, where haze effects are increasing, it is possible that RBV-1 ocean scene contrast may even be slightly lower than $\gamma 0.19$.)

5. The reproduction gammas for restoring the ocean images of RBV-1 and MSS-4 to surface contrast values were calculated to be $\frac{1.00}{0.19}$, $\gamma 5.26$, and for RBV-2 $\frac{1.00}{0.32}$, $\gamma 3.12$. RBV-5 is not used in the masking process, but only for estimating the order of haze effects included in the equivalent RBV-2 image.

6. All image reproduction is now carried out in the format illustrated in Figure 1. For example, the radiometric correction mask is pin-registered to RBV-2 on this format, and the calibrated control tablet is positioned at A, openings B through H being blocked. A gamma 1.0 negative is then produced, with exposure adjusted to place key image densities on the straight line of the print film response curve, gamma being determined from the reproduction of step tablet at A. In the next step, the negative, which is now corrected for radiometric error, is printed as the working positive image, with the control tablet moved to B, openings C through H being blocked. Exposure is again adjusted to reproduce key image densities on the straight line of the positive curve, and processing is given to produce gamma 1.0 as measured on the densities obtained in B. A cross-check on the net reproduction gamma and any deviations can now be made on the densities reproduced in A, which is in the 2nd generation. Data are plotted on a form of the kind shown in Figure 2, as a quick means of visualizing deviations in desired reproduction, checking for inaccurate density measurements, and for determining corrections in gamma necessary in successive stages of image reproduction.

7. This procedure was followed in making an MSS-4 negative at $\gamma 5.26$, and also an RBV-1 positive at the same gamma, according to plan. RBV-2 was remade as a positive at $\gamma 3.12$. For these high gamma levels it was necessary to use process and lithographic films. As all key image areas, from low-reflectance water to high-reflectance cloud had to be exposed

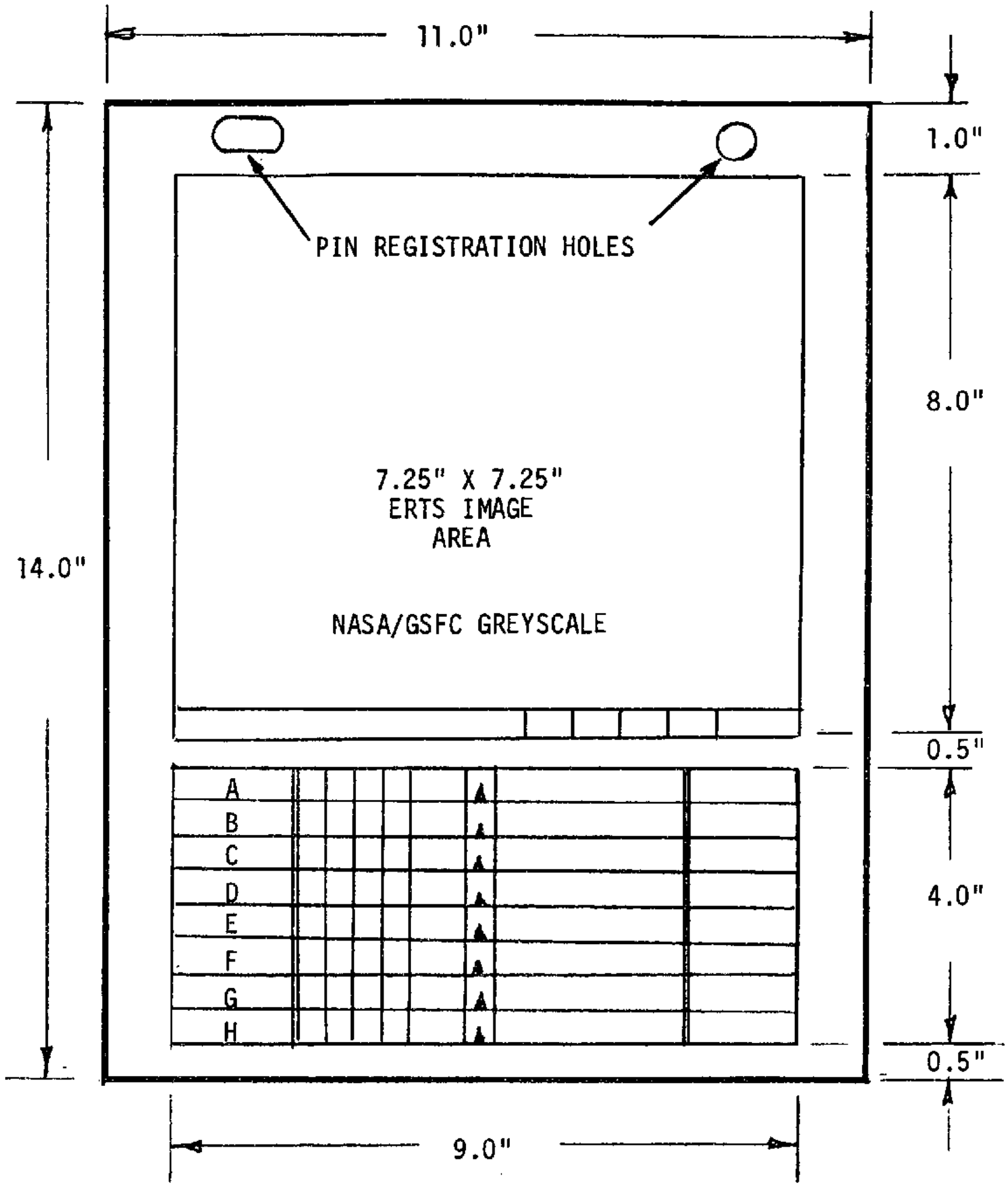

Figure 1 LOCATION OF ERTS IMAGERY AND CALIBRATED 21-STEP SENSITOMETRIC CONTROL TABLET POSITIONING ON 11X14-INCH REPRODUCTION FILMS. CONTROL TABLET IMAGES ARE REPRODUCED IN THE REQUIRED SUCCESSION INDIVIDUALLY AT POSITIONS A THROUGH H. PIN REGISTRATION MAINTAINS IMAGE REGISTRATION FOR RBV RADIOMETRIC CORRECTIONS, POSITIVE AND NEGATIVE MASKING AND CONTROL TABLET IMAGE POSITION.

I^2S International Imaging Systems

SENSITOMETRIC DATA SHEET

DATE: 24 Aug 73

PREPARED BY: PF/DSR

PROJECT NO.: C-200

TITLE: MSS-4 original pos to 1st gen. neg

FILM (TYPE): GRAVURE POS

DEV.: 5' DK-50 TEMP.: 68°F

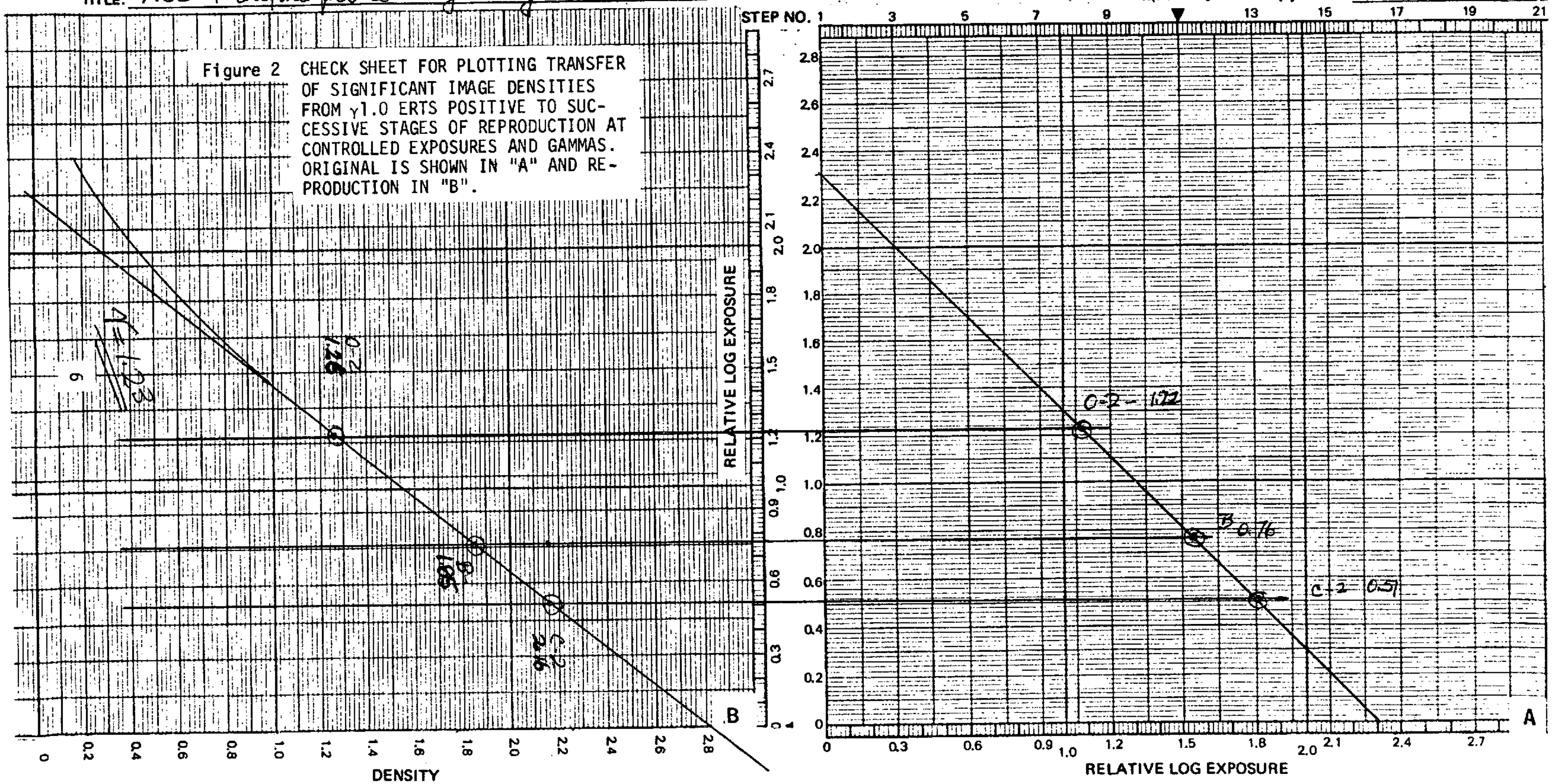

Figure 2 CHECK SHEET FOR PLOTTING TRANSFER OF SIGNIFICANT IMAGE DENSITIES FROM γ1.0 ERTS POSITIVE TO SUCCESSIVE STAGES OF REPRODUCTION AT CONTROLLED EXPOSURES AND GAMMAS. ORIGINAL IS SHOWN IN "A" AND REPRODUCTION IN "B".

FOLDOUT FRAME 1

FOLDOUT FRAME 2

on the straight line part of the reproduction curves, high density levels were entailed. When the high gamma MSS-4 negative was masked with the high gamma RBV-2 image, additive densities above 5.0 resulted (0.001% transmittance). Also, in masking, one clear film base thickness unavoidably occurs between the positive and negative images and the material being printed.

Exposure is made by a point-source light at 1.5 M from the vacuum printed to obviate diffusion of image detail.

PROBLEMS

8. The long exposure times required to print through the RBV-2/MSS-4 pos-neg sandwich produced serious halation and film base light-piping, particularly in the control tablet areas. Various ways around this were tried, such as by adding neutral densities over the control tablets, and edge-masking clear areas with opaque materials, but none was adequate in suppressing the defects, and the resulting images were not considered to be usable for the project insofar as sensitometric control was concerned.

CURRENT AND PLANNED WORK

9. It was decided to start over, producing gamma corrections gradually during the different stages of reproduction. To reduce the net densities

it is required to print through, sensitometric tests were made on Kodak Separation Film emulsions, Gravure Positive, and similar films, to select those with linear reproduction at low density ranges. Final images could then be reproduced at the required end gammas while avoiding excessive image densities in the intermediate stages.

10. Gamma required to correct ground level scene contrast (real scene gamma) between MSS-4 and RBV-2 is 5.26 to 3.12, or a ratio of 1.68 to 1.00. Work is in process of making a negative of MSS-4 at $\gamma 1.68$ to be masked with a positive image of RBV-2 at $\gamma 1.0$. The product will be a positive image of MSS-4, representing scene densities contributed in the 490-580 nm band. The positive and negative densities in MSS-4 and RBV-2, arising from spectral overlap between the two bands in the 580-600 nm region should cancel, and the new positive image should theoretically have only the densities representing scene-reflectances between 490 nm and 580 nm. When processed at $\gamma 1.0$, the effective scene contrast in the ocean areas, which were at $\gamma 0.19$ in the original, will now be raised to $\gamma 0.32$ ($\gamma 0.19 X \gamma 1.68$) at this stage of reproduction.

11. The spectral relationship of RBV-1 and -2, and MSS-4 is shown in Figure 3. The combination of MSS-4 negative and the RBV-2 positive mask interacts to block the 580-600 nm region in the new reproduction of MSS-4. To do this effectively, image density ranges must be adjusted, between the positive and negative images, in generating the new 490-580 nm MSS-4 positive. For exposure control, densities of

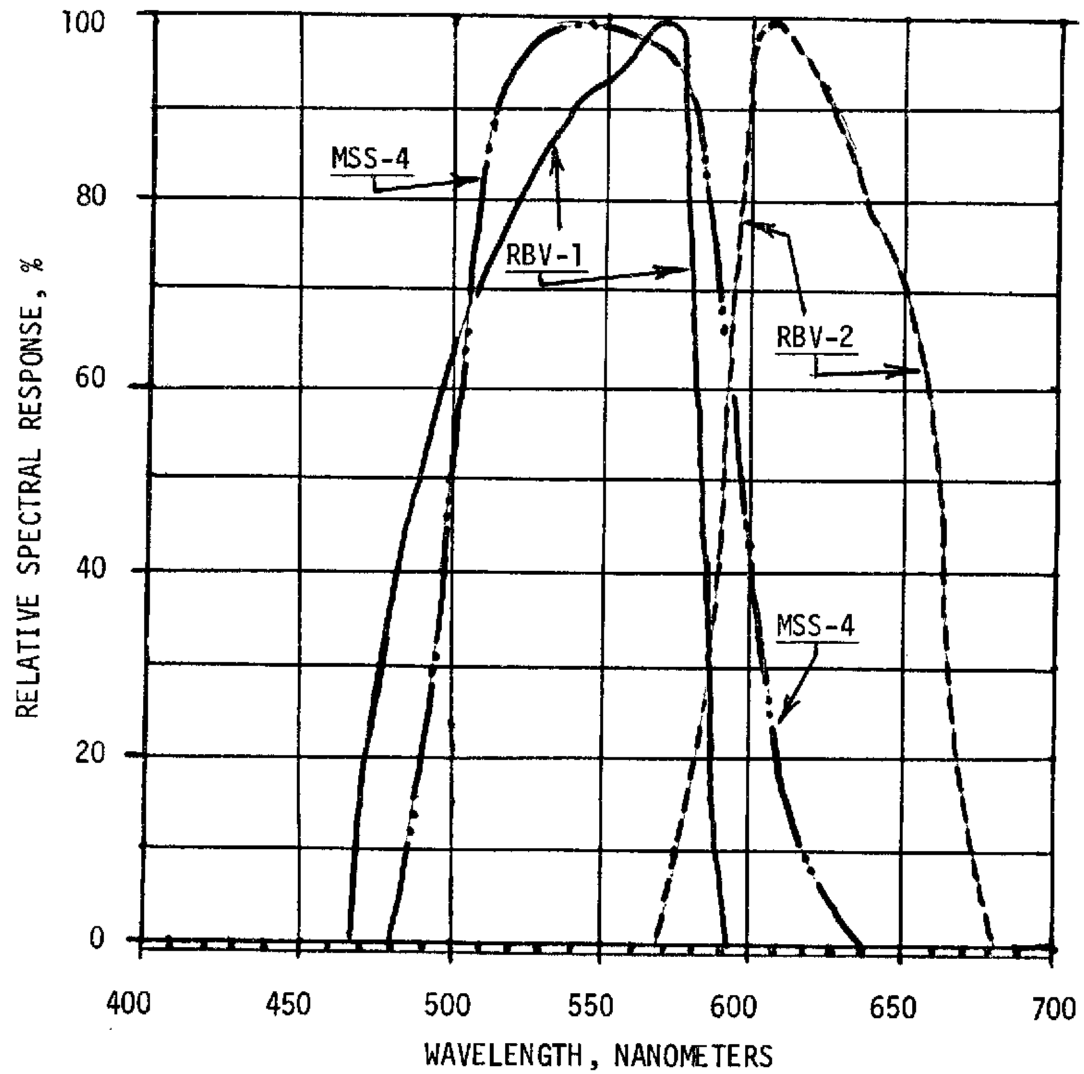

Figure 3 - SPECTRAL RELATIONSHIPS OF ERTS-1 RBV BANDS 1 AND 2, AND MSS-4, DERIVED FROM NASA/GSFC DATA USERS HANDBOOK (RBV) AND GSFC CALCULATED RESPONSE (MSS).

cloud and deep water image areas will be used as references, when this stage is reached, and will be cross-checked against the control step tablet densities.

12. As the cloud should appear in both positive and negative images as 100% sensor response (100% scene reflectance), the combination should be such that the cloud is just cancelled from the new image; however, since a spectral scene difference exists between the two images, densities representing less than 100% sensor response will not necessarily cancel. MSS-4 has densities representing the green and yellow component of water color in the shallow areas, but only green in the deep region. RBV-2 records the yellow and red bottom reflections in shallow water, but these colors should be absent from the surface of deep water. In the RBV-2 positive deep water will have a high density while the same area in the MSS-4 negative is much less. In printing through this combination shallow areas of the positive and negative densities common to both images in the yellow region of the scene should cancel each other, also the tail of MSS-4 which extends slightly into the red region. However, densities attributable to green energy reflected from the bottom in shallow water (or from the surface of deep water, if present) will be retained, since RBV-2 should not have recorded any green light energy.

13. Mis-Match Between RBV and MSS Input Positives. As noted in an earlier report, a slight discrepancy exists between image scales in the RBV and MSS images, making registration difficult. Possibly a more serious problem is found, however, when the NASA/GSFC grey scale steps are compared, as they are not linear to each other:

NASA/GSFC GREY SCALES

Step	RBV-1 (ΔD)		RBV-2 (ΔD)		MSS-4 (ΔD)		MSS-5 (ΔD)	
1	2.32		2.30		2.29		2.30	
		.32		.29		.52		.53
2	2.00		2.01		1.77		1.77	
		.53		.55		.52		.52
3	1.47		1.46		1.25		1.25	
		.29		.31		.21		.23
4	1.18		1.15		1.04		1.02	
		.20		.19		.15		.12
5	0.98		0.96		0.89		0.90	
		.18		.13		.10		.10
6	0.80		0.83		0.79		0.80	
		.13		.12		.09		.10
7	0.73		0.71		0.70		0.70	
8	(Steps 8 and higher have insignificant deviations.)							

14. The RBV sets agree with each other in ΔD, as do the MSS images, but ΔD's in the highest densities in the positive images deviate between MSS-4 and RBV-2, according to the GSFC Grey Scales. The gross densities of the same ocean area in the three images concerned are:

	RBV-1	RBV-2	RBV-4
Ocean area	1.05	1.00	1.22

These readings include base/fog, as do the associated greyscale steps. Deviations between the RBV and MSS ΔD's related to the deep ocean image density range are:

Steps	RBV-1	RBV-2	Steps	MSS-4
4-5	.20	.19	3-4	.21
5-6	.18	.13	4-5	.15
6-7	.13	.12	5-6	.10

At this time it is considered that a sufficiently linear agreement exists between the three images, at density levels which include the deep water image areas.

SIGNIFICANT RESULTS

15. No new significant results are reported.